MODIS DATA STUDY
TEAM PRESENTATION

May 3, 1991

AGENDA

1. Action Items
2. MODIS Ocean Data Products List
3. Global Topography Working Group Meeting
4. Assumptions/Tracking List

ACTION ITEMS:

04/26/91 [Lloyd Carpenter and Team]: Review the request for MODIS product information that was received from Paul Hwang, compile required information, and draft a reply letter by May 10th. The request has been reviewed, and the required information is being compiled. In many cases the required information must be inferred from the proposals. STATUS: Open.

04/26/91 [Lloyd Carpenter and Phil Ardanuy]: Provide a detailed breakout of the MODIS Level-1A and Level-1B data volume estimates provided by the SDST for the data compression workshop. Correct the column labels in one of the presentation slides. Breakout and corrections completed. STATUS: Open.

04/26/91 [Team]: Contact the University of Miami to determine their data quality control requirements for Level-1A data. Continuing to attempt to contact U. Miami. STATUS: Open.

04/26/91 [Lloyd Carpenter and Team]: Determine the instrument point-of-contact for data issues relating to the MODIS-N and MODIS-T instruments and initiate discussions relating to features of the instrument/ground-processing-system interface. Dick Weber (286-5992) suggested we contact John Barker with any questions relating to MODIS-N. John Barker was not available (SEB assignment). Bill Browne (286-3570) suggested (for MODIS-T) Bill Barnes (286-8117) for specifications, Tom Magner (286-5282) for hardware, and Mike Roberto (286-4004) for data systems questions. Discussions will be initiated. STATUS: Open.

04/26/91 [Team]: Review the MCST distribution of MODIS Geometric Knowledge and Control Assessments, identify salient points, and recommend future related SDST activities. Will be presented by Phil Ardanuy. STATUS: Open.

SALIENT POINTS OF MODIS-N/T REQUIREMENTS ON GEOMETRIC KNOWLEDGE & CONTROL

The above MCST report addressed questions found in GE's EOS Instrument Pointing Questionnaire of December 5, 1990. Requirements were derived for the geometric knowledge and control of the EOS-A platform from the differences between the total science requirements, the current instrument specifications, and the currently stated data processing designs. However, the ultimate proof of the instrument requirements lies in the impact of geometric, radiometric, and spectral instrument property changes on the derived geophysical products. This can only be quantitatively derived through perturbation analyses and simulations (either complete system simulations of using surrogate, e.g. aircraft data).

Ground Truth Observation by MODIS

There is no capability for real-time processing of MODIS-N or MODIS-T data. Therefore, there is no capability to provide information for attitude control of the observatory. 90% of the time, MODIS will not be able to help in providing any sort of control function or ground truth to the platform on any time scale. Under some selected conditions over large scale surface features (e.g., coastline between Sahara Desert and Mediterranean Sea), MODIS-N/T might provide an attitude resolution on scales as fine as the pointing knowledge of the instruments (90 arc seconds is currently held in the specifications).

Orbit Position Knowledge

The present MODIS orbit position knowledge requirement (three sigma, per axis) is 68m. If the platform attitude and instrument pointing knowledge improves substantially, then position knowledge could potentially increase to $50m/\sqrt{2}$, or 35m.

Cross-Track Ground Track

The MODIS cross-track ground track consistency requirement is ± 15 minutes in local time of overpass at each latitude for the course of the mission. The requirement applies at all latitudes.

Radial Orbit Position

In the case of MODIS-T, the scan mirror is presently being designed to rotate at 6.6 RPM, yielding a scan period of 4.54 seconds. Given the platform orbit of 233 revolutions in 16 days, a 98.88 minute orbital period is implied. For a mean Earth circumference of 40,000 km, an effective average velocity of 6.74 m/sec on the Earth's surface is obtained. 30 contiguous 1.1 km ground-fields-of-view will sweep out 33 km in a single scan, while the platform travels only 30.6 km. As such, an overlap of 2.4 km between scans is obtained. The radial orbit position would need to increase by on the order of 30 km to cause gaps between scans. The MODIS-T requirement is that the radial orbit position be 705 km $\pm$ 30 km.

The MODIS-N requirement is not known at this time due to the proprietary nature of the design.

Geocentric vs. Geodetic Coordinates

The need for topographic corrections for off-nadir locations and directional and bidirectional reflectances over land require geodetic coordinates. Compatability with the gridding schemes of existing data sets will also require geocentric coordinates. It must be possible to routinely convert from one coordinate system to the other.

Avoidance Concerns

(a) Lunar Calibration: The MODIS instruments must never directly view the Sun. For MODIS-N, this corresponds to angles in the YZ plane $\pm 55°$ from the +Z axis. For the MODIS-T instrument, this depends on the tilt. Nominally, MODIS-T will view ±45°across-track for tilts of the scan plane ±50° in the X direction. When MODIS-T tilts to the +X axis to view the Moon (over the north pole), this creates a geometry that will result in a direct solar view if the geometry is not changed in the half-orbit before the southern terminator crossing. **A +X axis tilt of 90° for lunar calibrations must never be allowed to persist south of the Equator.**

(b) South Polar BRDF Development: MODIS-T will be used to conduct snow/ice studies and BRDF model development over the poles. Over Antarctica, the potential exists for MODIS-T to view the Sun. For an Earth horizon at 64° off nadir, the edges of a MODIS-T scan will view space for tilt angles just above 51°. The Sun will rise above the pole at a nadir angle between 64° and a TBD minimum angle >51° (depending on season, local time of the ascending node, altitude, etc.). Therefore, the maximum tilt for MODIS-T in BRDF (stare) mode should either be limited to ±50°, or strict controls should be on monitoring the maximum limiting angle for tilts in the +X direction over the South Pole.

Calibration Attitudes

Both MODIS-N and MODIS-T will use the Moon as a calibration source. In the case of MODIS-T, however, lunar views will be acquired by tilting forward off-Earth from 65° to 90° near the northern terminator during periods near full Moon. The Moon will be imaged during the course of normal scanning. For MODIS-N, where a calibration port will likely be used to view the Moon, no definitive answer can be given until the MODIS-N contract is signed.

Instrument Pointing Knowledge

The MODIS atmosphere and ocean disciplines do not have driving requirements on line of sight and attitude (pointing) knowledge. Atmosphere products will be produced at horizontal resolutions from 5 km to 0.5° to 1° of latitude. Ocean products in coastal regions will be generated and studied at 1 or 1.1 km resolutions. However, the >0.5 MODIS-T IFOV navigation ability implied by the 108/90 arc second platform/instrument knowledge is adequate (Esaias, personal communication, April 18, 1991). Over the open oceans, the knowledge is more than adequate. For coastal/regional studies, some manual navigation could be used if necessary to improve the rectification.

The MODIS land discipline drives the pointing knowledge requirement. The MODIS science team plans to produce a daily global land Vegetation Index product at 1 km spatial resolution (Product #2749). This product has a projected accuracy of 1%, against required accuracies of 5%, 10%, and 15% (i.e., by IDS investigators Hansen, Simard, and Moore). Townsend et al. (1991), in "The Impact of Misregistration on Change Detection," have considered the sensitivity of NDVI to navigation accuracy. The study did not consider platform attitude knowledge, platform position knowledge, and instrument pointing knowledge independently, but rather the effect as a whole. The Townsend study considered a 10% error of NDVI at a 250m resolution to be the minimum desirable. They found that a 50% error in NDVI could derive from a 1-pixel (250m at nadir) mislocation, and that a 0.2 pixel uncertainty (50m at nadir) would be required to reduce the NDVI retrieval errors to 10%. A required accuracy of 10% at 1 km implies a 200m navigation error, while Jim Hansen's 5% accuracy requirement suggests a 100m navigation requirement. The 10% error limit for a 250m grid, requiring navigation to about 50m at nadir is the most stringent requirement.

These requirements suggest that either multi-(date, orbit) image matching techniques be employed, that improved platform/instrument knowledge be obtained, or some combination of the two. **Navigation to 50m to 200m (15 to 60 arc seconds) appears to be a well-founded scientific goal, if not a requirement, for this product**, and hence the MODIS-N instrument. This is a more stringent requirement than that presently carried platform PMP attitude knowledge of 108 arc seconds (each axis, three sigma), and the MODIS-N/T instruments (90 arc seconds; each axis, three sigma).

Note that MISR may have the capability to derive improved attitude knowledge at the MISR payload mounting plate (PMP). This would be accomplished by using stereo views to build a digital elevation model (DEM) [in cloud-free, land areas only] that could be referenced against a global DEM. With position known, the unknown quantity would be the MISR line of sight, itself dependent on the platform's attitude. Over oceans, the accuracy would be a function only of the platform/instrument pointing knowledge. It is assumed that improved accuracy in post-acquisition pointing knowledge for MODIS-N and MODIS-T could be obtained from: (1) ground control points over land using the MISR instrument; (2) a model of the slowly varying change in platform attitude with position in orbit; and (3) a pre-launch known, or in-orbit calculated, relative attitude of the MISR instrument relative to that of the MODIS instruments.

Definitive attitude and position products are desired with the same timeliness as the Level-0 data. This way, the definitive data may be appended as a part of standard Level-1A processing and used in Level-1B and higher processing. (As distinguished from post-processed products that may be available from the FDF days after real time.)

Instrument Instrument Pointing Accuracy

For MODIS-N, there is no explicit pointing accuracy requirement since MODIS-N will not be pointable, but will simply scan across track.

The total along-track field of view for the MODIS-T instrument is 33 km at nadir. The specified aiming accuracy about the cross-track (Y) axis must ensure the ability to locate and track a target near nadir **in Stare Mode** for BRDF model development. For a 10 km by 10 km target, there will be 0.5 x (33 - 10) = 11.5 km tolerance on each side of the target. A total pointing accuracy of 3600 arc seconds boresight linear sum between the MODIS-N instrument and the platform will yield an aiming uncertainty of 12 km for nadir observations. This would be an acceptable navigation of the MODIS-N data in stare mode. Off nadir, the pointing variability will increase in spatial units (e.g., meters on the ground). However, the angular uncertainty, relative to the size of the field of view, would remain the same. For MODIS-N, a 250 by 250 m pixel at nadir would be on the order of 1 km by 500 m at a 55° tilt angle. For MODIS-T, the pixel sizes will vary not only by scan angle, but also tilt angle, as shown in the attached figure.

In **Lunar Calibration Mode**, the Moon at 0.5° angle will fill about 6 MODIS-T detectors. 0.5 x (33 - 6) = 13.5 km tolerance on each side of the target will be once again met by an instrument plus platform 3600 arc second pointing knowledge.

The MODIS requirement would then be 3600 arc seconds, perhaps split equally between the platform and instrument as 1800 arc seconds platform; 1800 arc seconds MODIS-T; 3600 arc seconds boresight linear sum.

Instrument to Instrument Coregistration

MODIS-N to MODIS-T:

There are requirements on the coregistration of the MODIS-N and MODIS-T observations. This will be important at Levels-1B through 3. The requirements will be driven by the need to: (1) produce joint, consistent gridded data product fields [for example, combining Level-2/3 MODIS-N and -T ocean color products into a joint Level-3 dataset to eliminate missing data near the solar declination due to tilt changes]; (2) to transfer spectral information from one MODIS instrument to another [e.g., clear/cloudy/mixed pixel information at a 1.1 km MODIS-T ground IFOV from a group of 250m visible/NIR pixels as well as 1 km thermal infrared observations from MODIS-N]; and (3) for intercomparison and cross-validation of the two MODIS instrument data sets.

When this requirement is considered, the joint pointing knowledge uncertainty of the two MODIS instruments, and among all EOS instruments, is crucial. These may not be independent, as thermal distortion will be a function of orbit and will be correlated (positive or negative). Assuming uncorrelated, for root sum of squares purposes only, the RSS of two 90 arc second values yields 127 arc seconds, or about 430m at nadir (per axis). Coregistration of 1 km resolution radiances with 43% error will have severe scientific implications. To use MODIS-N cloud information with MODIS-T data analysis for ocean products, perhaps >1% area misregistration would cause unacceptable contamination. This is equivalent to 10% of the IFOV, or 30 arc seconds, in each axis. (At a 5 km spatial resolution, MODIS-N and MODIS-T will be coregistered to better than 90% of an IFOV.) Because there will be no requirement on the MODIS instruments to synchronize scans or IFOVs, there is no capability of influencing the relative pixel alignment between instruments through platform specifications.

MODIS-N to Other EOS Instruments:

The transfer of MODIS-N cloudiness information to MISR will be most useful at a 250m spatial resolution.

The transfer of MODIS-N cloudiness to AIRS will be important for the synergistic usage of the two data sets. With the AIRS instrument's 15 km nadir IFOV, there does not appear to be any requirement more stringent than that for the MODIS-N/platform pointing knowledge.

The transfer of MODIS-N cloudiness information to CERES will be a key EOS science requirement. This will not be a driver due to the 30 to 35 km CERES nadir footprints.

The cross-instrument data requirements imply that the coregistration capabilities and requirements of EOS instruments, both boresighting at platform integration as well as in orbit, should be critically examined.

Requirements on MODIS Data Processing

During extreme (>40°) MODIS-T tilt changes, data would continue to be taken. The requirements for navigation and possible interpolation should be understood. Any candidate navigation scenario using anchor-points should be evaluated under realistic operational conditions which include extreme tilt changes.

MODIS At-Launch Ocean Products

1.	A measure of Fluorescence Line Height (FLH)	Abbott
2.	High resolution, fast delivery SST field	Barton
3.	Weekly (archived) global SST field	Barton
4.	Radiometer Calibration	Brown
5.	Sea Surface Temperature (SST)	Brown
6.	Chlorophyll A	Clark
7.	Total Suspended Matter	Clark
8.	Oceanic primary production.	Esaias
9.	Water-Leaving Spectral Radiances	Esaias
10.	Time Averaged Marine Phytoplankton Biomass and Carbon Fixation	Esaias
11.	Calibration, Validation and Quality Control, Ocean Visible Bands	Evans
12.	Atmospheric correction	Gordon
13.	Concentration of detached coccoliths	Gordon
14.	Phycoerythrin	Hoge
15.	Chlorophyll Fluorescence	Hoge
16.	Phycoerythrin Pigment Concentration	Hoge
17.	Chlorophyll Fluorescence using Spectral Curvature Algorithm	Hoge
18.	Absorption (at 440 nm) due to eukaryotic phytoplankton	Parslow
19.	Absorption (at 440 nm) due to gelbstoff	Parslow
20.	Absorption (at 440 nm) due to non-chlorophyllous particulates	Parslow
21.	Back-scatter coefficient (at 550 nm) for total particulates	Parslow
22.	Angstrom coefficient for particulate backscatter	Parslow

MODIS Post-Launch Ocean Products

1.	Chlorophyll concentration	Abbott
2.	Florescence efficiency	Abbott
3.	Primary productivity	Abbott
4.	Land surface temperature (LST)	Barton
5.	Spectral surface emissivity	Barton
6.	Comparisons with SST from other instruments	Barton
7.	Case II chlorophyll algorithm	Carder
8.	Case II degradation products (absorption coefficients) algorithm	Carder
9.	Total dissolved organic carbon algorithm	Carder
10.	Backscattering coefficient at 565 nm algorithm	Carder
11.	Case II suspended sediments algorithm	Carder
12.	Flag-type algorithm to designate Case II waters algorithm	Carder
13.	Beam attenuation (520 nm)	Clark
14.	Diffuse attenuation for (PAR) and suspended organic particulate matter fraction	Clark
15.	Oceanic primary production.	Esaias
16.	Water-Leaving Spectral Radiances	Esaias
17.	Time Averaged Marine Phytoplankton Biomass and Carbon Fixation	Esaias
18.	Global-scale maps of the coccolith concentration	Gordon
19.	CZCS pigments	Gordon
20.	Diffuse attenuation coefficient at 490 nm ($K_d(490)$)	Gordon
21.	Single scattered aerosol radiance and Ångstrom exponent	Gordon
22.	PAR incident on the sea surface	Gordon
23.	Chlorophyll for Case-II Waters	Hoge
24.	Dissolved Organic Matter (DOM)	Hoge
25.	Species Diversity Imagery	Hoge
26.	Phycocyanin Concentration	Hoge
27.	Chlorophyll in Case-II Waters using Spectral Curvature	Hoge
28.	Dissolved Organic Matter (DOM) using Spectral Curvature	Hoge

TOPOGRAPHIC MISSION DEFINITION WORKING GROUP MEETING
April 29 - 30, 1991
Marriott Key Bridge Hotel, Rosslyn, VA

PROVISIONAL AGENDA

Monday, April 29th

9:00	Welcome	Walter
9:15	Meeting Objectives, Review Agenda	Vetrella
9:30	Future Directions. Procedure and Schedule for Convergence on Choice of Technology.	Dozier
11:00	Review of Requirements	Vetrella, Dozier
12:30	Lunch	
1:30	Review of Requirements, con'd	Vetrella, Dozier

TECHNIQUES MODELING AND ANALYSIS, STATUS OF FLIGHTS AND TESTS

3:00	Radar Interferometry	Zebker
5:00	Close	

Tuesday, April 30th

8:30	Laser Altimetry	Bufton
10:30 Muller	Optical Stereoscopy	
12:00	Lunch	
1:00	Documentation Outline, Writing Assignments	Dozier, Vetrella
5:00	Close	

ASSUMPTIONS/TRACKING LIST
for
The MODIS Level-1B Processor Design
MODIS Science Data Support Team
2 May, 1991

This document contains not only the design assumptions used to derive the Level-1B design but also a list of items that need to be tracked or resolved as part of the overall MODIS Data Study Team. The assumptions lists for the other levels of the MODIS data system design should be consulted for additional assumptions and tracking items.

Anchor Point Coordinate Systems

Earth location at the anchor points will be in the Latitude-Longitude coordinate system when appended to the Level-1B Data Product. The locations will be determined within the MODIS Level-1B program internally in a cartesian coordinate system corresponding to the EOS inertial coordinate system. The Earth will be represented by the oblate spheroid (two axis ellipsoid) Earth Model using the 1984 coefficients. Forward and reverse transforms to and from these coordinate systems will be generated and/or approved by the EOSDIS office to ensure that all instruments data in addition to MODIS data will be properly registered.

Data Granule Sizes

The science content of the Level-1B data granule will be spatially equal to or smaller than the Level-1A data granule. This implies that only one input data set (Level-1A product) will be required to produce one or more output (Level-1B data product) data sets. The Earth ground coverage of the Level-1B data granule will be less than or equal to the Earth ground coverage of the Level-1A data granule.

Browse Requirements

It has been assumed that there are no Browse data set generation requirements on the Level-1A program. These are expected to be performed in the Level-1B processing, although they have not been included in the design at this point.

Land/Ocean/Other Flag

The current design for the Level-1B Data Product includes the provision for calculating the ground location of the pixels at selected points across the scan (anchor points) using a calculated Earth model without any correction for elevation. This is purely a geometric calculation and gives the Earth oblate spheroid intersection with selected instrument IFOVs in addition to azimuth and elevation (zenith) angles to the Sun and satellite from the selected ground anchor points. Any use of a terrain elevation data set for further correction of the pixel locations (ground anchor points or all scan pixels) is delayed until the Level-2 processing. This philosophy brings up many points of discussion, such as why are ground locations performed in Level-1B processing (cloud determination perhaps) instead of MODIS IFOV pointing vectors, when should an land/ocean flag be determined, and if an off-Earth or Moon looking indicator should be included? This area needs further clarification with appropriate logical decisions from the various land, ocean, and atmospheric users instead of following historical precedent.

Science Data Quality

There appears to be some interest in performing a science data validity check based upon the science imaging data only, perhaps as a histogram of imaging data. The comparison of ICC data with telemetered data has been deleted from the level-1A processing leaving the desire for imaging verification in the level-1B processing. Many data quality checks in addition to the obvious status checks could be performed by either the MODIS or Characterization processes. These may include frequency domain transformations (i.e. Fourier), inter-band covariance, and spatial statistics.

In-Situ Data Requirements

It is assumed that no in-situ data input is required to generate MODIS Level-1B products. This item will be determined by the calibration and characterization team. If in-situ data is required then navigation must be performed to determine the MODIS instrument radiance values corresponding to this ground based data. The possibility exists for more than one orbit (Level-1A granule) of data to be required to find the necessary in-situ located radiance values. If this is true, have these required orbits been processed before or after the current orbit? The resolution of this item has been deferred until a later date (TBD by J. Barker et al).

Data Availability

The design currently has a provision for asking the DADS for the data set sizes and completeness rather than assuming that the SCA process will determine this information as part of the scheduling activity. This assumption requires the MODIS processor to have decision making ability to determine the desirability of continued processing if the data set is incomplete or a similar anomaly has been detected.

Anomaly Detection

The design has provisions for generating control flow messages upon the detection of an event or problem from the telemetered data, where a problem is designated as a potentially catastrophic problem and an event is a non catastrophic event. The messages are passed internally within the MODIS-1B processor to a control section that posts the messages to the MODIS Processing Log. The messages may then be passed to external processing functions via the SCA if it would be desirable. A list of problems and anomalies to be checked will be determined at a future date when the instrument specifications are further defined. These messages do not apply to any comparison with the ICC command log.

Data Compression

The processing design has no provision for performing any type of data compression. Any data compression is assumed to be performed in an external (to the MODIS processor) process, utilizing either a software or hardware approach.

MODIS-T Tilt Stability

An assumption is made that an indicator in the telemetry stream will be provided from which the stability of the tilt angle can be determined. This may be a 'tilt in progress' bit or an encoder before and after science scan position or similar indicator. The best current information on the instrument indicates that a 40 degree tilt may be performed and the tilt stabilized during the back scan portion of the 4.5 second total scan interval. This would allow the stare and stair step modes to be accommodated without effecting the anchor point ground location accuracies.